A SEARCH FOR SOLAR-LIKE OSCILLATIONS IN α Cen A

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Abstract. We have been using a new method to search for solar-like oscillations that involves measuring temperature changes via their effect on the equivalent widths of the Balmer hydrogen lines. We observed α Cen A over six nights in 1995 with the 3.9-metre Anglo-Australian Telescope and the European Southern Observatory's 3.6-metre telescope in Chile. Oscillations were not detected, with an upper limit only slightly higher than the expected signal.

1. Introduction

Many attempts have been made to detect stellar analogues of the solar five-minute oscillations. As with helioseismology, it is hoped that the measurement of oscillation frequencies in other stars will place important constraints on stellar model parameters and provide a strong test of evolutionary theory. However, despite several claims in the literature, it is fair to say that there has been no unambiguous detection of solar-like oscillations in any star except the Sun (see reviews by Brown & Gilliland 1994; Kjeldsen & Bedding 1995; Bedding & Kjeldsen 1998).

We have been using a new method to search for solar-like oscillations that involves measuring temperature changes via their effect on the equivalent widths of the Balmer hydrogen lines. We found strong evidence for solar-like oscillations in the G subgiant η Boo (Kjeldsen et al. 1995; Bedding & Kjeldsen 1995), with frequency splittings that were later found to agree with theoretical models (Christensen-Dalsgaard et al. 1995a,b; Guenther & Demarque 1996). Since then, the improved luminosity estimate for η Boo from Hipparcos measurements has given even better agreement (Bedding et

al. 1998). However, a search for velocity oscillations in η Boo by Brown et al. (1997) failed to detect a signal, setting limits at a level below the value expected on the basis of the Kjeldsen et al. result. More recently, Brown et al. (private communication) have obtained a larger set of observations which they are currently processing.

2. Observations of α Cen A

We chose η Boo as the first target for the equivalent-width method because this star was expected to have an oscillation amplitude about five times greater than the Sun. This turned out to be the case (assuming the detection is real). We then turned to α Cen A, a more challenging target because of its smaller expected oscillation amplitude (comparable to solar; Bedding et al. 1996). Being a near twin of the Sun and extremely nearby, this star is an obvious target for detecting oscillations (e.g., Brown et al. 1994). Previous attempts to detect oscillations using Doppler methods were reviewed by Kjeldsen & Bedding (1995) and include two claimed detections at amplitudes 4–6 times greater than solar (Gelly et al. 1986; Pottasch et al. 1992) and two negative results at amplitudes about 2–3 times solar (Brown & Gilliland 1990; Edmonds & Cram 1995).

We observed α Cen A over six nights in April 1995 from two sites:

– at Siding Spring Observatory in Australia, HK and TRB used the 3.9-metre Anglo-Australian Telescope with a coudé echelle spectrograph (UCLES). We recorded three orders centred at Hα and three orders at Hβ. The weather was about 85% clear.
– at La Silla in Chile, SF and THD used the European Southern Observatory's 3.6-metre telescope with a Cassegrain echelle spectrograph (CASPEC). We recorded three orders centred at Hα. The weather was 100% clear.

3. Results and simulations

Data processing of the 20,000 spectra was carried out by HK using the method outlined in Bedding & Kjeldsen (1998). The power spectrum of the resulting time series of equivalent-width measurements is shown in Fig. 1. No obvious excess of power is seen – note that earlier reports of a positive detection were premature (Kjeldsen et al. 1996; Frandsen 1997). The average noise level in the amplitude spectrum (square root of power) is 4.7 ppm, which is somewhat higher than expected purely from photon noise. One extra noise source arises from wavelength-dependent fluctuations in the continuum, which appear to arise from a colour term in the scintillation (Jakeman et al. 1976; Dravins et al. 1997).

The strongest oscillation modes in α Cen A, as measured in Hα equivalent width, are expected to have amplitudes of about 8 ppm, while the solar peak amplitude is about 6 ppm (Bedding et al. 1996).

To set an upper limit on oscillation amplitudes from our observations, we have generated simulated time series consisting of artificial signal plus noise. Each simulated series had exactly the same sampling function and allocation of statistical weights as the real data. The injected signal contained sinusoids at the frequencies calculated by Edmonds et al. (1992), modulated by a broad solar-like envelope centred at 2.3 mHz (which is the expected frequency of maximum mode power – Kjeldsen & Bedding 1995). In each simulation, the phases of the oscillation modes were chosen at random and the amplitudes were randomized about their average values. All these character-

istics were chosen to imitate as closely as possible the stochastic nature of oscillations in the Sun. Before calculating the power spectrum, we added normally-distributed noise to the time series, so as to produce a noise level in the amplitude spectrum of 4.7 ppm (consistent with the actual data).

Some results are shown in Fig. 2. The top panel shows that a signal with an amplitude of 12 ppm would be easily detectable in our data. It is interesting to note that some of the signal peaks in this simulated power spectrum have been strengthened significantly by constructive interference with noise peaks. For example, a signal peak of 12 ppm which happens to be in phase with a 2-σ noise peak (2×4.7 ppm) will produce a peak in power of 450 ppm^2. This illustrates the point made by Kjeldsen & Bedding (1995; Appendix A.2): the effects of noise must be taken into account when estimating the amplitude of a signal.

The next four panels in Fig. 2 show simulations in which the strongest modes had amplitudes of 8 ppm, the value expected for α Cen A. In some cases, excess power is seen and there is perhaps some hint of regularly spaced peaks. However, the actual data (bottom panel) are clearly consistent with an 8 ppm signal and we conclude that the observations did not have sufficient sensitivity to detect a signal of this strength. We can probably set an upper limit of about 10 ppm.

In summary, our results rule out oscillations at a level slightly less than twice solar, making α Cen A the most stable known extra-solar star. The corresponding upper limit in velocity is about 50 cm/s.

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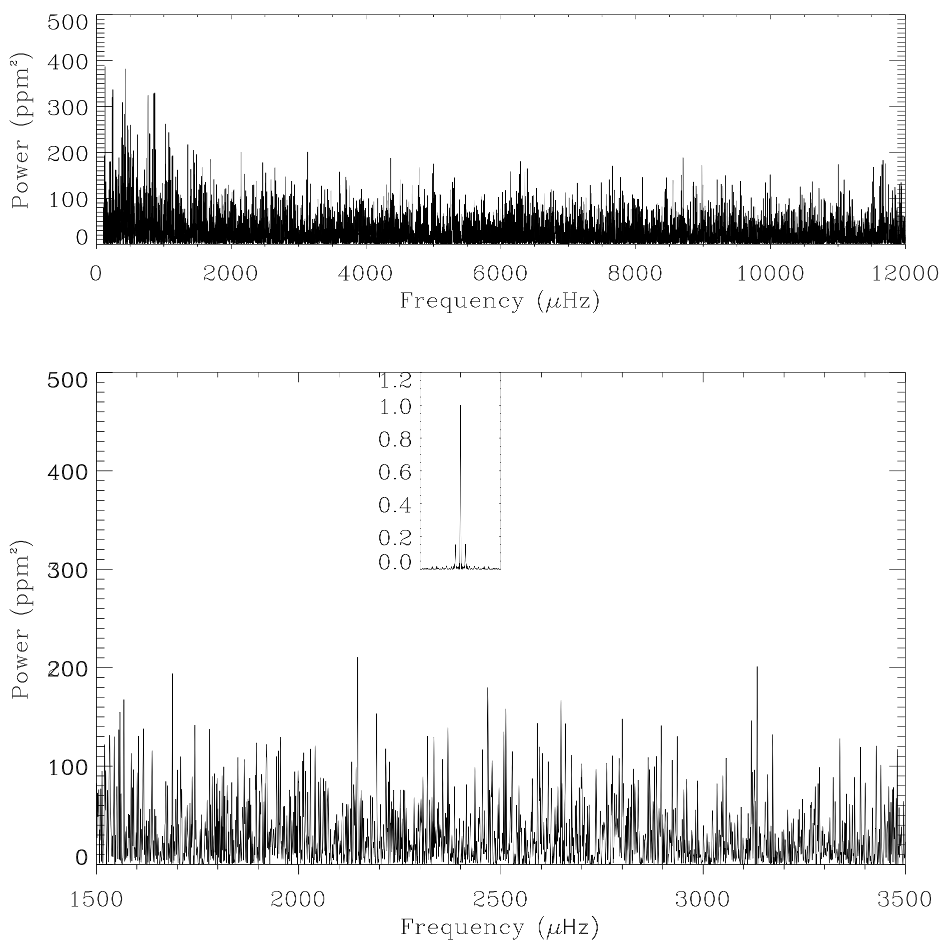

Figure 1. Power spectrum of equivalent-width observations of α Cen A. The lower figure is a close-up of the region where signal would be expected, and the inset shows the power spectrum of the window function.

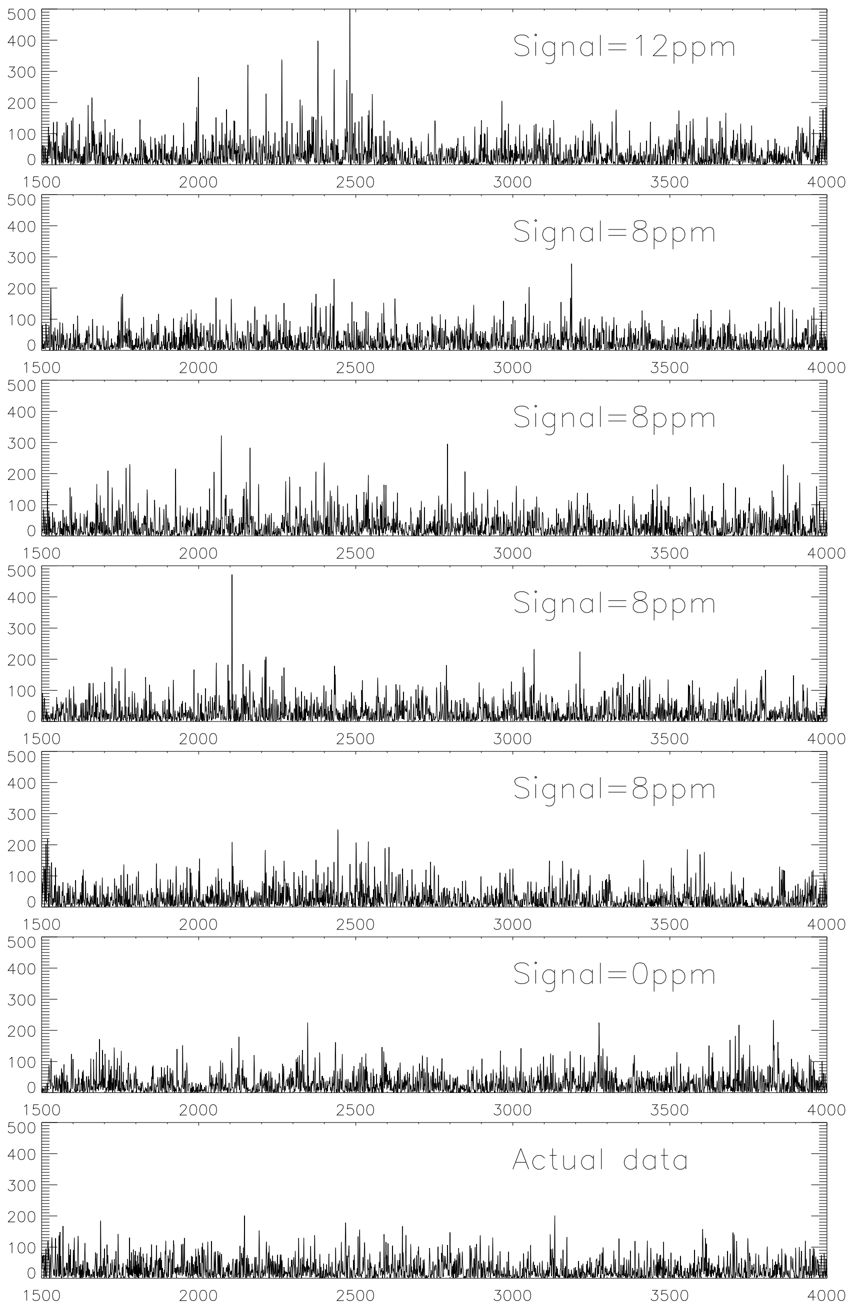

Figure 2. Simulated power spectra, using the same sampling times and data weights as the actual observations.